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To make or to buy - an approach to making that decision with regard to national weapons acquisition.

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NAVAL POSTGRADUATE SCHOOL

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AN APPROACH TO MAKING THAT DECISION
WITH REGARD TO NATIONAL WEAPONS ACQUISITION

by

Richard Edmund Walters

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The smaller sophisticated nations have to decide where to procure their weapons systems. Though these smaller countries are probably capable of designing and manufacturing their own systems, this is not necessarily the most economically efficient use of their resources. This paper canvasses some of the issues involved in a make or buy decision. It then suggests a cost/benefit analysis as one way of applying a value to the

pros and cons of the alternatives of make; buy; or varying shades of a mixture of the two. It further suggests that the whole of life costs, rather than the acquisition costs, should be the basis for the decision process and then that the alternative with the highest net present value should be the one selected.

To Make or to Buy - An Approach to Making that Decision with Regard to National Weapons Acquisition

by

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

The smaller sophisticated nations have to decide where to procure their weapons systems. Though these smaller countries are probably capable of designing and manufacturing their own systems, this is not necessarily the most economically efficient use of their resources. This paper canvasses some of the issues involved in a make or buy decision. It then suggests a cost/benefit analysis as one way of applying a value to the pros and cons of the alternatives of make; buy; or varying shades of a mixture of the two. It further suggests that the whole of life costs, rather than the acquisition costs, should be the basis for the decision process and then that the alternative with the highest net present value should be the one selected.

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I. INTRODUCTION

Australia is one of a number of smaller nations which possesses a well-established, sophisticated industrial base. In theory, it has sufficient resources to undertake the necessary research, development and production required to satisfy its own defence needs. History shows, however, that Australia has preferred to purchase a substantial proportion of its requirements overseas. These purchases have been from the larger industrialised Western nations, usually in the face of considerable opposition from its own industrial and trade union sources.

All things being equal, it would seem that a government should prefer to obtain its defence equipment from its domestic infrastructure. There must be compelling reasons for it to do otherwise. Primary reasons revolve around such issues as dependability, higher value uses for the required resources, comparative advantage and acceptable delivery times.

The Australian Government has recognised that it faces difficult decisions in this area during the procurement of major defence items such as weapons systems. On June 3rd, 1984, it issued a "Defence Policy for Australian Industry". [Ref.1] The thrust of this policy is that Australia would like to have a strong defence industry but that there are

costs to such an approach. In general, defence equipment manufactured in Australia costs more, in dollar terms, than equivalent equipment procured overseas. It is necessary to identify the economic effects of possible courses of action before deciding where to have equipment manufactured. The Government stated in its "Defence Policy for Australian Industry" that where the total cost of procuring equipment in Australia is higher than the total cost of buying it elsewhere, then the equipment should not be purchased in Australia unless there are strategic reasons for pursuing a domestic procurement.

Clearly, the best possible estimation of the likely total costs and total benefits of alternative courses of action is germane to the final decision. The Government recognised this when it said in its statement:

> "There is a need for (the Departments of) Defence and Defence Support to employ more formal processes that identify the benefits and penalties of local industrial capabilities and of Australian participation in specific equipment programs to allow assessments to be made against alternative support options and competing force structure and infrastructure needs, to the maximum extent possible - (the Department of) Defence is to provide policy guidance which is to include the specification of important local capabilities and acceptable cost premiums for their retention and development." [Ref.1]

This paper will explore one approach to deciding whether to make at home or to buy from another country. The methodology will be to draw a decision tree in order to raise the issues that need to be addressed before proceeding from one decision node to the next. Each issue raised will be

addressed in a general manner and the reader will be directed to further, more detailed discussion should he need it.

It is assumed that the Project Director or Program Manager will be charged with the responsibility for marshalling the necessary arguments and information to allow him to draft the required submissions for consideration and eventual approval by higher authority. This paper is directed at him in the belief that he is unlikely to be an expert on many of the issues raised and will consult with specialists as necessary. It is intended primarily as a tool to assist the project manager in pursuing a structured approach to establishing the best line of action for his project. All projects are different and will almost certainly require different levels of emphasis on particular points. The answers to many of the questions raised will be obvious, other questions may well be difficult, if not impossible, to answer.

The decision tree approach is meant to assist in identifying the particular issues involved and the alternative approaches which may be taken. The next stage is to quantify, as best as possible, the costs and benefits of each alternative. The net present value of each alternative approach should then be calculated in order to identify the one which results in the least cost to the taxpayer.

While the discussion is addressed to the Australian situation in particular, it should have general application

for other nations and even for large companies which are faced with a 'make or buy' decision.

II. THE DECISION TREE

A. CONVENTION USED

The three pages which follow depict one decision tree. The symbols used are those recognised internationally for flow chart logic diagrams. In the United States, they are recognised by the American National Standards Institute (ANSI) under code Y32 14.

The only exception to this is the letter which is to be found alongside each decision node. The purpose of this letter is to direct the reader's attention to the particular section of Chapter III where a list of issues that might be addressed at that node is to be found.

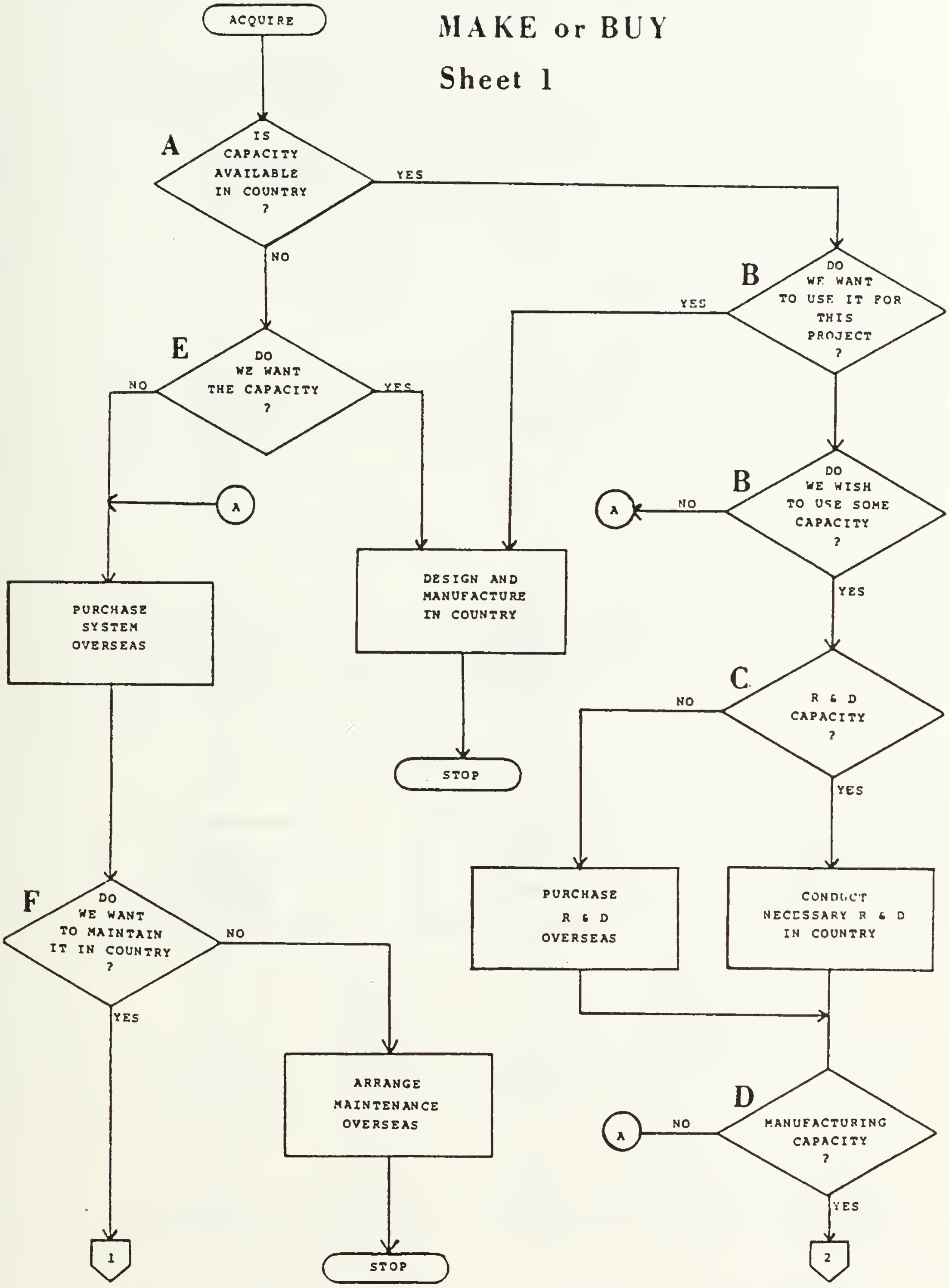

Figure 2.1 Make or Buy Flowchart - Sheet 1

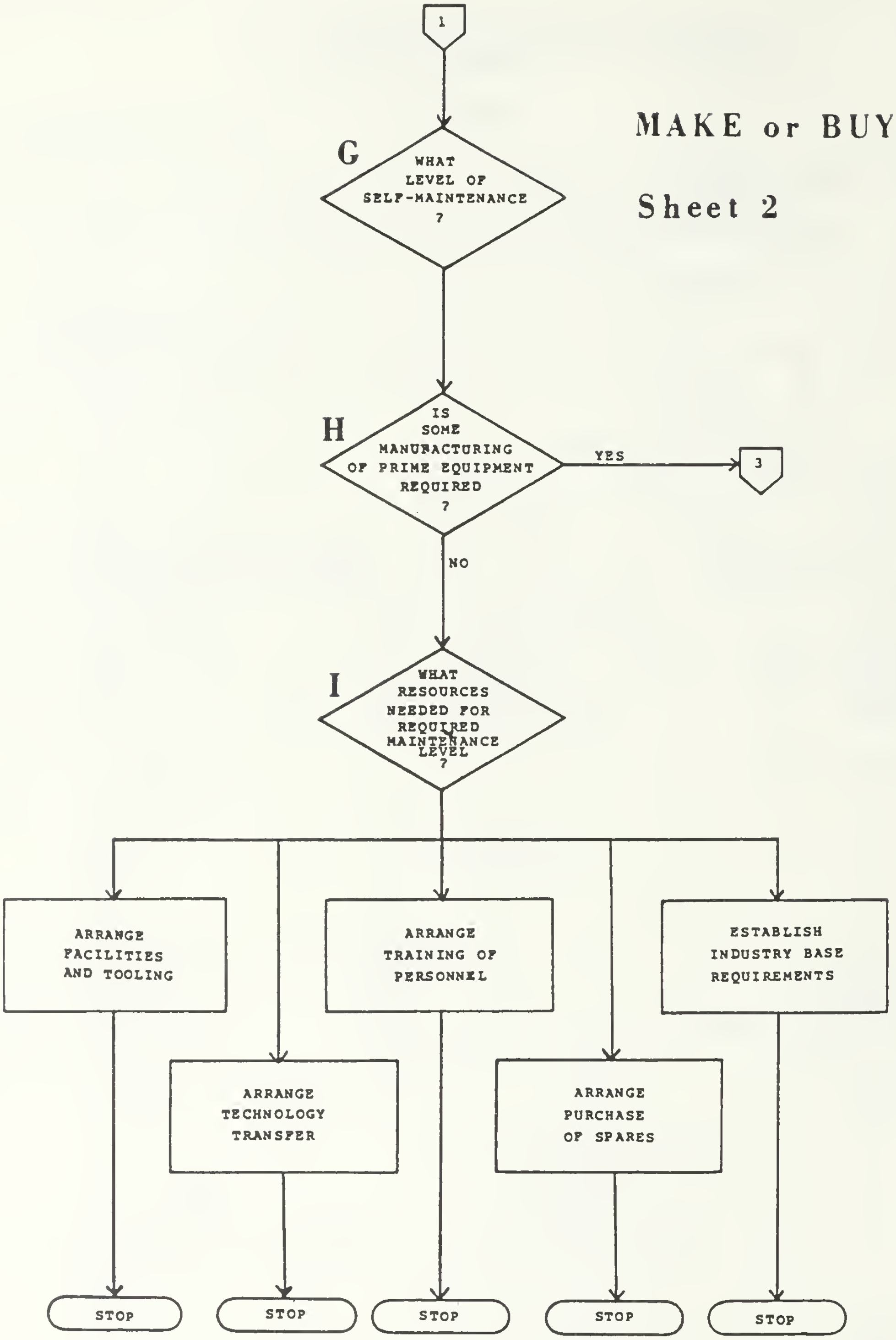

Figure 2.2 Make or Buy Flowchart - Sheet 2

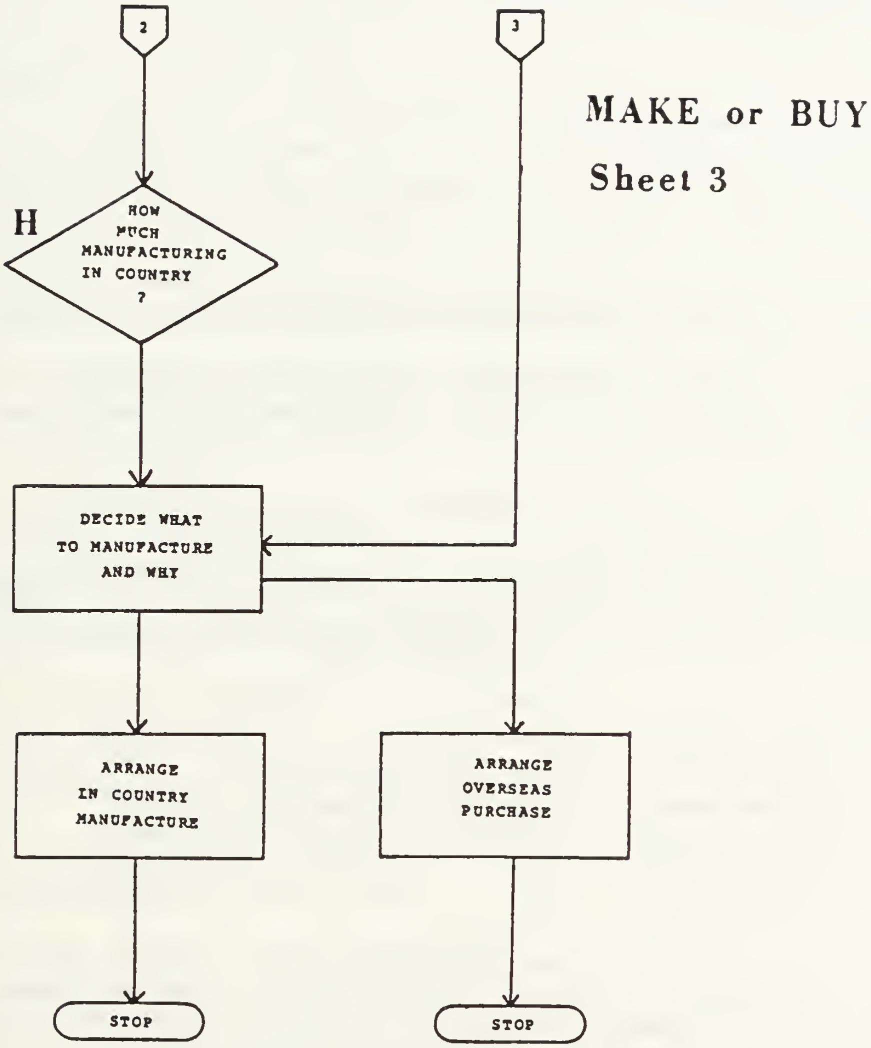

Figure 2.3 Make or Buy Flowchart - Sheet 3

III. ISSUES INVOLVED

This chapter is a listing of issues that might be addressed at each of the decision nodes identified in the previous chapter.

A. IS CAPACITY AVAILABLE IN-COUNTRY?

1. Are all the required equipment and facilities available?

2. Are there sufficient people with the needed skills available in the right places to complete the project?

3. Is the required technology available? (Comment - this is probably not an issue if 1 & 2 above are positive).

B. DO WE WANT TO USE THE CAPACITY FOR THIS PROJECT?

1. Is the capacity already being used for something else?

2. Is there an identified higher value use for the capacity?

3. What will happen to the capacity if we do not use it?

4. What is the cost of using our capacity against the cost of having the weapons system produced overseas?

5. What is the social cost of not using our capacity?

6. Even if we do not wish to procure the whole weapons system in-country, is there some part of the process that we wish to undertake using existing facilities and skills?

7. Can those parts of the project which we wish to undertake in-country be successfully interfaced with those parts undertaken elsewhere?

8. Are prospective overseas suppliers likely to allow parts of the system procurement to be undertaken outside their direct control?

C. RESEARCH AND DEVELOPMENT CAPACITY

1. Do we wish to develop all or part of the weapons system in-country and then have it completed elsewhere?

2. Why do we wish to conduct R & D?

   a. Because we have the capability? (See A & B above).

   b. Because we want the capability? (See F below).

D. MANUFACTURING CAPACITY

1. Do we wish to manufacture to an overseas design?

2. Do we wish to manufacture the whole of the weapons system or just parts of it?

3. Why do we wish to conduct manufacturing?

   a. Because we have the capability? (See A & B above).

   b. Because we want the capability? (See E below).

E. DO WE WANT THE CAPACITY?

1. What will it cost to obtain the technology or facilities to undertake the project?

2. Is this a worthwhile investment?

   a. Is there likely to be a continuing requirement for the capacity after this project is completed?

   b. Are the technologies acquired likely to have other applications?

3. Can we afford the investment?

4. Are the sought-after technologies and facilities required to operate and maintain the weapons system in service? (See G below).

F. DO WE WISH TO MAINTAIN THE SYSTEM IN-COUNTRY?

1. Do we have the necessary technologies and facilities to undertake maintenance?

2. To what level can we be self-sufficient?

3. Is this a sufficiently high level to operate the system?

4. What is the likelihood of obtaining the required level of maintenance elsewhere if needed?

5. What are the costs of conducting maintenance elsewhere?

6. Is it possible to operate the system at maximum effectiveness without being able to maintain it?

7. Do we wish to improve and adapt the performance of the system over time? What is the required level of maintenance skills to be able to do this?

G. WHAT LEVEL OF SELF-MAINTENANCE DO WE REQUIRE?

1. What is the highest standard of performance required of the system likely to be?

2. What level of maintenance capacity is required to meet this standard?

3. Do we require to have this maintenance capacity available in-country or can we rely on timely availability elsewhere whenever it is needed?

4. Does the required level of maintenance dictate an R & D and/or manufacturing capacity?

5. Is it economical to stockpile all required spare parts?

H. IS SOME MANUFACTURING OF PRIME EQUIPMENT DESIRABLE?

1. Are manufacturing skills necessary in order to perform the required levels of maintenance?

2. What skills?

3. Is it necessary to have these capabilities at whatever cost?

4. Is it desirable to minimise the money being spent overseas on the project?

5. Can we manufacture some components of the weapons system as cheaply as, or cheaper than, the prime manufacturer?

6. Can we sell components as a co-producer?

I. WHAT RESOURCES ARE NEEDED FOR THE REQUIRED MAINTENANCE LEVEL?

1. Will already planned manufacturing facilities provide all these resources?

2. What other suitable resources are already in-country?

3. Will these resources be available when required?

4. What resources will we have to acquire?

a. Facilities.

b. Tooling.

c. Documentation.

d. Personnel skills.

e. Spare parts.

f. Reserve industry capacity.

IV. CAPACITY

A. INTRODUCTION

The first questions with regard to a 'make or buy' decision concern capacity. If the acquiring country does not have, and does not want to invest in, the required capacity, then the question becomes merely one of where best to buy the proposed system overseas.

Capacity is here defined as the total ability to bring into operational service a weapons system or pre-determined parts of that system. It includes the necessary raw materials, capital equipment, technology and labour (human resources). These items need not necessarily be in-place at the time that the 'make or buy' decision is made, however there has to be a credible plan for acquiring the necessary inputs so that they are available as needed. When looked at from this standpoint, it is difficult to envisage under what circumstances economically advanced countries such as Australia would lack the capacity to develop, manufacture and bring into service any weapons system as, in an absolute sense, the financial means are available to purchase the necessary resources. There are certain areas where a country may lack the will to involve itself in a particular technology. A good example of this is provided by those nations that are signatories to nuclear non-proliferation

pacts. This latter point is generally a non-issue, however, as countries are unlikely to wish to acquire weapons systems that use technologies to which they are unwilling to subscribe.

The key to any reasoned analysis of the 'make or buy' decision may be a cost/benefit analysis of using capacity to produce all or part of the desired weapons system against acquiring the system by some other means, for example outright purchase or leasing. This holds true whether a country is under constant threat, such as Israel, or one which cannot identify any specific threat, such as New Zealand. The difference between the two is that the former country almost certainly places a much higher value on acquiring, in a short time-frame, an operational system which has guaranteed maintainability. It is therefore more prepared to forgo other uses for its capacity.

The cost/benefit analysis is very complex as it involves national interests and looks many years into the future. It is a matter of national strategic planning and involves such intangibles as 'the national interest', 'foreign policy' and 'system integrity'. A reasonable insight can be gained, however, if the question of 'make or buy' is broken down into its component parts and then those parts which have quantifiable costs and benefits are identified and analysed. The unquantifiable issues need to be identified and then listed. Politicians are elected and paid to make decisions

on such matters. It is the duty of the service materiel command to attempt to quantify only those issues to which a monetary value can be attached and to leave to the politicians those unquantifiable issues which can be loosely described as policy.

The issues raised in Chapter III are now discussed in more detail. The object is to identify the issues and discuss them in general terms. No effort is made to quantify costs and benefits as this can only be done on a case by case basis.

B. IS CAPACITY AVAILABLE IN-COUNTRY?

1. Availability of Equipments and Facilities

The purchase of a major weapons system requires a comprehensive mix of capital equipment and facilities. These capital investments are normally part of the domestic economy, though some final assembly and testing facilities, such as a navy-owned dockyard or a missile test-range, may have only military applications. The general parameters of the desired weapons system are likely to be known early in the process. It should be a fairly straightforward task to prepare an inventory of the sorts of facilities and capabilities required and then compare this against what is available now and what is planned to be added or deleted in the time-span of interest. It is especially important to identify those features of a weapons system that are likely

to be difficult to satisfy, for example facilities for bending, rolling and welding submarine pressure hulls; construction material for aircraft skins; and casting and machining of artillery barrels. These are applications which are usually not required in the domestic economy and may not be available when required. The cost of providing such facilities must be weighed against the likely outputs of these facilities over their designed useful lives. The designed life of any major plant is likely to far exceed the time span of the envisaged weapons system acquisition project. Thus any likely future uses for the plant need to be identified and taken into account when calculating the net cost of acquiring any particular capacity. A method of calculating the net cost will be discussed in Chapter VI.

2. Human Resources

As with capital investment, human investment lends itself to being inventoried. It is generally held that labour is more mobile than capital investment, however it is important to identify the labour that is needed to operate the equipment and facilities envisaged. Is it available in the needed quantities, with the right skills, at the right location? The cost of moving labour is high, and getting higher, as society becomes more sophisticated. Frequently, labour is unwilling to move because it is locked into a particular location. This is particularly true of skilled, semi-skilled and unskilled labour. There may be two or

three incomes in the family unit to support the cost of the home; or the family may well be living in government subsidised or controlled rental accomodation; or children may be attending local colleges. From the workers' point of view, they must see themselves as being better off after a relocation than they are at present. There must be reasonable certainty as to continuity of employment at the new location for the worker to adopt this happy point of view. Continuity of employment requires the identification of follow-up projects.

Even though the costs of relocating labour are high, the alternative of retraining labour is equally costly and something which the nations of the western World are notoriously poor at. A properly financed comprehensive worker training programme is a rarity in the public domain and is usually undertaken in the private sector at the middle to higher management levels rather than at the skilled worker level. Australia has employed a policy of importing skilled labour but this source now has less significance than it had in the past. The costs of retraining people include not only the direct training costs but also the costs of keeping the trainee and his dependents in the style to which they have become accustomed. An often overlooked cost is that of the loss of productivity of the trainee in his old occupation while he is being trained for the new one. The benefit is that, hopefully, a person's productivity will be

significantly enhanced after his course of training. A cost/benefit analysis in this area is difficult as many variables are involved and little useful research has been published.

C. DO WE WANT TO USE THE CAPACITY FOR THIS PROJECT?

1. Competition for Available Capacity

Having established that there is an in-country capacity, the next step is to investigate the availability of that capacity for the project under consideration. The program manager needs to identify, in general terms, those facilities and skills for which he is likely to find difficulty in gaining the necessary allocation. Projected difficulties may be due to either a limited amount of the required resources being in existence or to high usage rates for the known resources. In either case, there is a situation of scarcity and a need for the country to allocate the available resources to the highest value uses. For example, a country might have two manufacturers of electric generators and motors. It may have projected requirements for generating sets for use in exploiting underdeveloped areas, generators and motors for new diesel electric locomotives and motors to drive pumps for an irrigation scheme. The project manager needs to understand the effect that adding a requirement for similar equipment for a new class of

conventionally powered submarines might have and what competition there is likely to be for the resources he requires.

The simplest way of conducting such an investigation is to call for bids to undertake the work and then allow free market forces to establish the true cost of employing those resources. This avenue is unlikely to be available, however, as such approaches are generally considered to be unethical and, in any case, take too long to complete.

The alternative of estimating the costs and the most efficient uses of the available resources by using the economist's tools of welfare economics and general equilibrium analysis is not yet developed to the point where it is practical for this purpose.

Therefore the project manager should resort to a cost/benefit analysis of his proposed actions. As both costs and benefits accrue to the taxpayer it is important that the task is carried out to the best of the program manager's ability, taking account of his limited resources and information. He should be as accurate and objective as possible. Cost/benefit analysis is discussed further in Chapter VI.

2. Idle Capacity

At the other end of the spectrum is the identification of capacity which is not being utilised and for which there are no planned competing uses. This time the reverse question has to be asked. What is the cost of not using

available domestic resources? Idle capital equipment depreciates in value and also requires maintenance to keep it operable. Capital investment in idle plant and machinery could have been employed to better effect elsewhere. The cost of not using available plant and machinery can be estimated using readily available, usually government-established, accounting factors. It has been estimated that the cost of idle capacity in the defence sector of the US aircraft industry alone is as high as $500 million per annum [Ref.3:p.177]. The cost of unemployed manpower can be partly calculated as the sum of the direct costs of unemployment and other welfare benefits and the loss of productivity of that manpower. Much more difficult to estimate is the toll on the individuals concerned. A person who does not use acquired skills tends to lose them, though the rate of loss is generally unquantifiable. An estimate can be made, however, by calculating the cost of an individual's training and then estimating the rate of loss of skills learned.

In the extreme, the non-utilisation of capacity will lead to its disappearance. An example of this was the loss of ability to design and manufacture saturated steam propulsion systems prior to the introduction of nuclear submarines. Should such a loss seem a possibility, then it is necessary to seek any other potential uses for that capacity. If it is desirable to retain idle capacity because of other uses, then the true costs of keeping that capacity

available should be adjusted to allow for other potential users to share in that cost. Where it can be established that a particular capacity must be maintained for some other use, then the cost allocation to the defence project under consideration for maintaining it should be zero.

Any identified excess capacity costs for undertaking the required work need to be taken into consideration when comparing domestic and quoted overseas prices.

3. <u>Use of Domestic Capacity for Partial Completion of the Acquisition</u>

Where it is agreed that the whole of a weapons acquisition project should not be undertaken in-country, it may well be attractive to complete parts of it overseas and parts at home. Indeed, for the smaller developed countries, this is the most likely scenario. Even the most sophisticated weapons systems use some technologies which have been established for considerable periods of time and which will have found their way into the industry bases of a number of countries. In such areas, the smaller countries may well be competitive with the major weapons supplier countries. An assembled and tested major weapons system is the product of the work of many sub-contractors. The British Polaris weapons system, for instance, utilised over 20,000 sub-contractors.

The management of the integration and construction of a warship, aircraft or tank is a major undertaking in

itself. To introduce component parts made in different countries adds to that task, and consequently to its costs, by increasing the project's complexity. Components made in different countries would, if not controlled, be produced to different standards and tolerances. The controlling of these standards leads to costs in the area of project management. These costs must be added to the quoted price of the domestically produced component parts to give the real cost of local manufacturing involvement, by using techniques which have been previously described. Increased manufacturing costs are generated by applying unusual standards to a particular manufacturer's work-methods and practices to ensure that his manufactured parts interface with the rest of the system. Generally, the domestic producer is acting as a sub-contractor to an overseas prime-contractor and so the domestic operation bears the cost of meeting these standards.

A major reason for seeking local component manufacture is to ensure that the capacity is available in-country to maintain the weapons system during its operational life. This aspect will be addressed in some detail in Chapter V.

4. Research, Development and System Design

The idea of using one's own scientists and designers to work on national weapons systems is intuitively appealing to the leaders of most developed nations, for reasons of national prestige. The dollar costs of R & D are high. For

instance Pratt and Whitney invested in excess of $1 billion to develop its PW 2037 turbine [Ref.2:p 8]. The cost to the US Department of Defense of developing the MK 48 torpedo is estimated to be in excess of $500 million [Ref.3:pp 34 & 102]. US Department of Defense experience has shown that less than twenty per cent of R & D expenditure is used on research and advanced development. At least sixty per cent of such funds is spent on full-scale development. [Ref.3:p 97] The smaller nations have to look at these very high initial costs and consider the numbers of systems over which the costs can be amortised. Additional opportunities where the R & D might be applied should be considered, including the likelihood of selling the technology developed to other potential users, either by way of manufactured equipments or by license fees. The project manager can have only general ideas in this area and should consult with trade and industry development professionals in order to target likely applications.

The true costs of research and development for individual systems are the estimated costs incurred, adjusted for the share which might be borne by other likely users of the new technology. Before embarking on a research and development program, it is wise to search the world technological base to identify any other developers of the required technology or acceptable substitutes for it. The

cost of purchasing the technology should be compared with the true cost of developing it domestically.

Economies of scale dictate that the larger nations, particularly the U.S.A. and the U.S.S.R., undertake the majority of research and development work as these countries are able to spread the costs over larger numbers of deployed systems. Because of the much larger economic bases from which they are operating, the results of failure of any one endeavour are much less severe than they would be in a smaller country.

The 'national interest' plays a significant part in R & D decisions and may well be the deciding factor. This may arise either because a particularly coveted technology is not available or because it is deemed essential to have total national control of it. Good examples of decisions in this area are provided by those economically disadvantaged countries such as India and Pakistan that see a need to possess a nuclear capability. South Africa has developed a number of its own weapons because it is denied access to recognised markets. Australia has developed systems in the Anti- Submarine Warfare field to suit its own particular needs as the thrust of NATO ASW development has been to produce systems, for use in the colder waters of the northern hemisphere, which are not ideally suited to Australia's warmer conditions.

The project manager should strive to obtain the required research and development at the lowest real cost, however it is possible that the 'national interest' will prevail on occasion. In this case it is a worthwhile exercise to estimate the cost of pursuing the latter goal to assist the politicians in their decision-making.

5. Production

Many of the arguments that apply to the use of R & D capacity for defence projects are relevant to the use of production capacity. It is generally easier to identify other uses for investment in production capabilities than it is for investment in R & D.

Economies of scale are particularly relevant. As the quantity produced increases, the true cost of producing each item should get closer to the variable costs of producing it (the marginal cost of production). The quantity produced per time-period is also important as this impacts directly on the efficiency of plant size. If it is envisaged that existing production facilities are to be used, then the closer the quantity produced per time period is to the capacity of the plant, the more economically efficient the operation becomes. If new plant is to be utilised, then the size of the plant should match the envisaged output rate in order to achieve maximum economic efficiency. It is more efficient to produce three ships per year in a yard designed

to produce that number of ships per year than it is at any other rate.

It is a generally accepted principle that the larger the plant, the lower the unit cost of production, providing that the plant is properly utilised. This should favour the larger country as it has a larger likely market. In theory, dis-economies of scale can occur. These rarely manifest themselves, however, because the larger a firm is, the more power it is able to exert over its resource suppliers in dictating the price of its inputs. Larger scale production may lead to learning curve advantages. Where a particular process is repeated, it should take less time to complete it each time it is done. The marginal cost of production should therefore decrease as production numbers increase. Buffa provides a good explanation of this process and shows simple methods by which the rate of reduction of costs can be estimated when they are subject to learning effects [Ref.4]. Learning effects require that human effort is involved in the process and that there is exact repetition. Any change in the process will negate some or all of the learning effect.

An avenue available to smaller countries is to specialise in the production of certain component parts of weapons systems. Countries should specialise in those products for which they have a comparative advantage. [Ref.5:p.23]

That is, a country should manufacture those goods which it does relatively most efficiently.

Where a weapon system is being acquired in part from overseas, the project manager should, in attempting to minimise the true cost of his project, consider a position of co-production where his country is supplying components used in the manufacture of all units of the weapons system and not just in those units being supplied to his country. This is generally well recognised and is the basis of many off-set production agreements.

Off-set production arrangements may also be based on in-country production of an overseas design. In many cases, this approaches an assembly and test operation with the majority of components being imported. The supplying country provides much of the technology and the coordinative management expertise. The advantage to the recipient country is that it does not involve itself in the high unit-cost R & D previously discussed but retains a considerable proportion of the project price in the domestic economy by conducting the comparatively labour-intensive tasks of assembly, testing and 'set to work'. As an added bonus, the acquiring country is generally able to use its own construction materials such as steel, wiring and pipework. This form of approach is likely to lead to the lowest real cost of acquiring weapons systems, as the recipient country is able to selectively buy, rather than produce, those items

and services which would present it with high real costs should it attempt to manufacture those items using its own resources. For instance, Australia is currently preparing itself to assemble F/A-18A aircraft. A composite fabrication plant has been commissioned which allows the airframe to be 'glued' together rather than being riveted. This process, the R & D costs of which were paid for by the US, will significantly reduce the cost of airframe production.

6. The Worth of Acquiring New Capacity

Related to purchasing high real cost items and services overseas is the question of whether a country needs the capacity at all. Should it be desired to acquire the ability to produce to a particular technology, it is necessary to consider the continued uses for that capability after the current project is completed. This may well apply to the F18 example just cited. If no other uses can be identified, then the entire costs of the capacity acquired should be set against the project. Any identified alternative uses will reduce that cost. The assessed cost of capacity acquisition should be compared with the likely 'off-the-shelf' cost of purchasing the completed goods or services overseas.

An often stated, but frequently misguided, reason for acquiring and maintaining reserve capacity is for industrial mobilisation. Discussion of the topic tends not to link the facilities sought with the scenario under which they will be used. For instance, it would seem unsound to

consider maintaining a reserve ship-building capacity where it takes four years to build a ship in a scenario which sees the maximum length of a credible conflict as being eighteen months.

Reserve capacity tends to become dated quickly. Minimal maintenance is carried out and the ability to exploit some technologies becomes limited. A good example of this is the rapid increase in the use of computer aided design and computer aided manufacture (CAD/CAM). The human skills required for CAD/CAM are very different from those that were in general use only five or ten years ago for manual drafting and machining. It is usually not possible to manufacture manually from drawings produced by and for CAD/CAM systems. Tolerances are of an order so different that mere man cannot perform to the required standards. In any case, the skills of the old toolsetter and machine operator are disappearing as few new personnel are being trained in these skills and older personnel retire. Such reserve physical capacity soon becomes worthless. Another example is provided by the US Army which has whole munitions factories in reserve. The plants are maintained, but there are no credible plans for staffing them with suitably skilled labour. [Ref.3:p.169] Before a decision is made to acquire a particular capacity, its likely useful life should be considered and costed accordingly.

V. MAINTENANCE REQUIREMENTS

A. INTRODUCTION

One of the issues raised in the previous chapter was the acquiring nation's desire to be able to maintain its weapons systems using its own resources.

The need to be able to operate and maintain all owned weapons systems without outside assistance is present in the strategic thinking of all the more technologically advanced nations, however there is some variation in the degree of their perceived need. The NATO countries, for example, have established a comprehensive mutual support and maintenance network as manifested by the Rationalisation, Standardisation, and Interoperability (NATO RSI) concept. Australia has taken a somewhat stronger stance on self-reliance as exemplified in a recent statement from Minister of Defence Scholes:

> "Labor's defence policy is in essence to develop a more self-reliant strategic posture based on the principle of developing independent national defence capabilities to deter conventional attacks on Australian territory." [Ref.7]

The desire for independence and self-reliance in the operation and maintenance of a nation's defence force is driven by the fear that foreign sources might be closed off when most needed. Such a situation might be caused by a deterioration in the relationship between supplier and buyer

nations, or by the intervention of a third party to stop estabished flows, or even by the supplier country deciding that it needs to keep its resources for its own use.

A plan to purchase cheaply overseas when coupled with a need to operate independently leads to a dichotomy. The most obvious way of ensuring an independent maintenance capability is to design and manufacture the prime equipment oneself. A move away from this position necessitates a trade-off between lower system acquisition costs and a higher risk of loss of independence. The previous chapter discussed acquisition issues. The purpose of this chapter is to raise issues involved in minimising the risks inherent in operating systems purchased overseas and then to identify the likely cost sources of so doing. Costs established in this manner should be set against the assessed savings of purchasing the prime equipment overseas before deciding the most cost-effective course of action to follow.

The maintenance costs of a weapons system are a significant part of its total through life costs. They are probably second only to manpower costs when all costs are reduced to their net present value. It may well be that a desire to minimise maintenance costs will affect the source of the system chosen, even to the extent that the lowest cost suitable prime equipment may not have the lowest overall cost of ownership. An example of this is provided by Australia which operates Leopard tanks and 42 metre patrol

boats. Both are equipped with MTU diesel engines. The Australian investment in MTU engine maintenance facilities is considerable. The next major investment in high speed diesel engines will be for a new class of submarines. While there are other diesel engine manufacturers whose products are priced competitively with MTU, the cost of providing facilities for maintaining additional MTU engines is likely to be considerably less than providing the necessary facilities for any other make of engine.

B. IN-COUNTRY MAINTENANCE

Any new weapons system added to the inventory will require maintenance procedures which are similar to others already carried out for existing equipments. It will most likely also require new procedures using technologies that are new to the Defence Force. It is important to identify these new procedures and evaluate whether they can be carried out successfully by using the nation's current industrial base. Where new industry base requirements are identified the next stage is to look at the most cost-effective way of satisfying them, bearing in mind national economic and defence philosophies.

First, an evaluation should be made of the integrity of the overseas prime source. Where it is decided that this source does not meet national requirements with regard to this point, an alternative method of maintaining the system

in operational condition needs to be established. There are several available options, such as the stockpiling of parts and sub-assemblies, purchase of the necessary technologies, establishment of a more secure foreign maintenance source or internal development of the required capabilities.

1. Stockpiling

Some stockpiling of spare parts and sub-assemblies will be required, whatever the relationship between supplier and buyer, in order to have inventory readily available to the user. Quantities of needed spares should be optimised using economic order quantity (EOQ) models, which trade off ordering costs and holding costs to achieve minimum overall inventory costs. A good coverage of EOQ models is provided by Rose who gives guidance on cost estimation under conditions of both stable and unstable demand for various levels of service. [Ref.7:Ch.6] Any additional quantities deemed necessary for war reserves should be estimated by first establishing the maximum credible time period for which supplies might be disrupted and then estimating the numbers of spares that would be required to cover that period. The holding costs of such an inventory can then be established quantitatively.

2. Technology Transfer

It may be possible, at the time of purchasing the prime equipment, to arrange for the transfer of any desired technologies. Such transfers may be arranged with few

restrictions on their use or they may be made under strict license conditions which preclude their use in other applications. If the former is the case, then the true costs of transfer can be shared among all likely users, however, in the latter case all the transfer costs have to be borne by the project. Any technology transfer arrangements are probably best negotiated concurrently with the contract for the prime equipment as this is the time when the supplier is most likely to be amenable to entering into such agreements, due to his desire to sell the prime equipment. The advantage of technology transfer over stockpiling is that holding costs, which can be considerable, are minimised. The disadvantage is that the technology has to be maintained at some minimum level which will allow it to be utilised when required. The costs associated with this approach are dependent on the assessed warning time available to bring the technology to the required level of readiness.

3. Other Foreign Sources

Using a third country to satisfy maintenance needs is particularly appealing to a country which has close ties, and probably land borders, with a country other than the one from which it is purchasing the prime equipment. Good examples of this strategy are provided by the European countries which provide mutual support for F-16 and Jaguar aircraft maintenance. Mutual support, providing it can be relied upon, leads to economies of scale savings.

4. <u>Internal Development of a Maintenance Capability</u>

This option allows a high level of self-sufficiency, however it is likely to involve high relative costs and higher risks. The recipient country develops its own maintenance philosophies and methods based on its experience with the equipment, supplemented by whatever intelligence it can glean from other sources. This approach is used out of necessity by such countries as Israel and South Africa and from time to time by others as they perceive other maintenance methods which better suit their needs. Such variations are often spawned by user modifications to equipments to satisfy national interests. An example of this is provided by Australia which has modified its F-111A aircraft weapon delivery systems to release domestically produced conventional bombs. The risks associated with a 'go-it-alone' policy are twofold in that significant problems may be missed due to the relatively small samples experienced; and in that a move away from the initial configuration may lead to costly problems if further modifications are envisaged.

The costs and benefits of instituting philosophies which rely on the independent development of a maintenance capability are difficult to predict as the problems likely to be encountered are, by their nature, unstructured.

C. PERFORMANCE LEVELS

As the required levels of performance of a system increase, then so do the likely costs. Minimum levels of acceptable performance need to be established early in the process as they will have a direct bearing on which maintenance philosophy is likely to have the largest ratio of benefits to costs. Such an approach may even eliminate some options altogether. The system performance level requirements of the supplier country should be compared with the aspirations of the buyer country and any variations noted and costed. Significant savings can be achieved by challenging performance levels which are set unnecessarily high by operational staffs.

1. Operational Availability

As operational availability requirements increase, then so does the necessity for timely repair and maintenance. The latter is acheived by higher investment in maintenance support in the form of both equipment and personnel. 'Repair by replacement' philosophies, with their high inventory investment in major sub-assemblies, progressively replace the lower cost 'repair in place' philosophies as availability requirements become more stringent. Higher levels of availability also require additional personnel. The ultimate example of this is the nuclear ballistic submarine which needs two complete crews and significant

numbers of highly skilled support personnel in order to achieve required availabilities of 95% or more.

2. System Performance Levels

The level of performance required of an individual system directly impacts on its maintenance cost. The higher the level of required performance and the smaller the tolerance of acceptable performance about that standard, the higher the maintenance costs become because corrective maintenance is required each time that system performance falls outside specifications. It is normal practice for weapons systems suppliers to quote ideal performance standards. Prospective buyers should assess the actual standards that are being used by the supplier nation's defence force to operate their systems and then set maintenance policies accordingly.

3. Early Establishment of Performance Levels

The earlier in the life of a project that performance levels are set, the better will be the information on which to base project decisions. Early decisions on maintenance requirements can lead to lower costs by allowing the buyer country to purchase investment spares (repairable items) at the same time as orders are placed for the items that will be needed to produce the prime equipment. This should ensure identicality of equipments and also lead to some savings due to economies of scale. The US General Accounting Office has estimated that such purchases should

save up to 20% of the cost of spares [Ref.8:p16]. Early decisions on operational performance requirements will assist with decisions concerning the level (depot, intermediate or operational) at which equipments will be repaired, and hence where facilities will be located. In general, the more work that can be undertaken at the depot level, the lower the cost of establishing the necessary facilities, due to the smaller numbers required.

VI. COST/BENEFIT ANALYSIS

This chapter relies heavily on unpublished work by Steve Cylke of the Economic Analysis Branch (OP-162) of the United States Department of the Navy, Deputy Chief of Naval Operations (Manpower, Personnel and Training). [Ref.9]

Previous chapters raised and discussed some of the costs and benefits that might be associated with purchasing weapons systems overseas or designing and manufacturing them using domestic resources. The objective of this chapter is to present a method of producing a valid analysis of the pros and cons for taking various courses of action. The purpose of this analysis is to materially assist the decision-maker in coming to an informed decision on the acquisition method to be used for a particular project. It is recognised that the project manager is unlikely to be a specialist in economic analysis and, furthermore, that his time and knowledge are too valuable to expect him to master the detail required to complete a comprehensive analysis himself. Rather, he needs to have an understanding of three things; the basics of the analysis; where he interfaces with the professional analyst; and what information he needs to gather and input to the process.

A cost/benefit analysis is one method of ordering alternative courses of action. It assigns a net present value to

each alternative. The course which has the highest net present value should be the one most deserving of detailed consideration for implementation. A good cost/benefit analysis leaves an auditable trail leading to how the decision was made. This is particularly important in the public sector where the project manager is charged, above all else, with giving the taxpayer the best value for money. It is easy to recognise the benefits of 'state of the art' technologies and forget their costs because the benefits accrue to the individual's organisation while the costs are borne elsewhere, ie. by the taxpayer. A cost/ benefit analysis weighs the benefits against the costs and gives a net present value for each course of action being considered.

The analysis consists of four stages:

1. Choose feasible alternative courses of action and define the useful life of the system;

2. Identify and quantify the costs and benefits of each course outlined in 1 above;

3. Derive the net present value of each alternative; and

4. Conduct a sensitivity analysis of each net present value computation.

A. CHOICE OF ALTERNATIVES

The previous chapter went some way towards discussing the alternatives for procuring a weapons system. Clearly there are numerous ways of accomplishing the acquisition, ranging from conducting the complete project in-country to purchasing the whole system package off the shelf overseas.

Government initiated constraints, such as the time scale within which the system must be operational, or mandated ways of achieving some of the phases of the project, may make some courses of action not feasible. The analysis then requires a trade-off between the number of feasible alternative ways to be analysed and the resources available to complete it. The project manager should choose the most likely set of alternatives, taking care not to prejudge some alternatives from the analysis because the benefits appear to be small. The costs may be even smaller.

The analysis should be a total length-of-ownership analysis and therefore the operational life of the weapons system needs to be established. The expected life of a particular system may well have been directed by higher authority as part of the project documentation. The further one looks ahead in a project, the less accurate the assumptions made become, however, where significant differences can be detected in the operating and maintenance costs of the different alternatives, the whole-of-life approach becomes an essential element of the analysis.

B. MEASUREMENT OF COSTS AND BENEFITS

The costs and benefits of each alternative should be identified and then measured. The project manager is likely to be the expert at identification but will most probably need help with measurement. It is important to note the

necessity of looking at the costs and benefits that will accrue to the nation rather than those that will accrue to the defence community. It is the nation that pays the costs and derives the benefits. A good analysis, which clearly identifies the national issues involved, is likely to be of assistance in obtaining the funding required to complete the approved course of action.

Where costs and benefits can be quantified they should be. Where they are identified but cannot be measured with any degree of accuracy, then the decision process falls back on subjective judgement. It is possible, however, to minimise the requirements for subjectivity. Even a checklist of benefits, set against quantified costs, can assist the decision maker by allowing him to ask the the question "If alternative A costs $n less than alternative B, are the additional benefits provided by B worth at least $n?". Any additional information on the benefits to be expected can only assist the decision-maker.

One particular problem facing the defence decision-maker is that defence is rarely sold on the open market. It is therefore difficult to compute, or even impute, a dollar value for the benefits. In the international versus domestic acquisition field, however, this problem can be eliminated by making the outputs of each alternative course of action equal, ie. the amount of defence provided by each alternative is made to be the same. It is preferable that

only the marginal costs and benefits of each alternative be considered. Where it is not possible to separate out the marginal costs and benefits, then a strenuous effort should be made to include all costs, so that those costs and benefits which are common to all options will cancel themselves out in the final analysis.

Where dollar values cannot be assigned to costs and benefits, the next best approach is to devise some system which assigns a preference value to the alternatives proposed. The alternatives can then be rank-ordered so that there is some degree of quantification. Where this approach is taken, it is necessary to document the assumptions made and the procedures used. The decision-maker can then assign his .pa own confidence levels to the analysis. Any structured effort to rank the alternatives is better than none.

C. CALCULATION OF NET PRESENT VALUE

All costs and benefits should be calculated at present value, even though it is known that they will be applied at some time in the future. The reason for this is that it is difficult enough to predict the rate of inflation let alone how a particular project will perform relative to that rate. This is particularly true in the international arena where different countries have different inflation rates. The best that can be assumed is that monetary exchange rates will themselves vary to equalise such differences. The rate

of inflation will affect all costs and benefits to the same extent and is therefore not a marginal cost in a cost/benefit analysis.

This having been said, it is a generally accepted fact that the present value of a dollar declines the further into the future it will be received or paid. This is the real rate of interest, or the time value of money. Most governments set a discount rate which is to be applied, by all their agencies, to future streams of benefits and costs. That is, they decide what is the value to them now of a dollar to be spent or received in one year's time. If, for instance, the discount rate is set at 10% per annum, the government is saying that a dollar paid or received now is worth the same as one dollar and ten cents to be paid or received in one year's time.

In order to carry out a net present value (NPV) calculation, the future stream of costs and benefits for a particular course of action should be established on a time-line and then each cost and benefit should be discounted to the present. All costs, at present value, should be totalled and then subtracted from the totalled present value of the benefits. The resulting figure is the net present value of the alternative. Alternatives can then be rank-ordered, the one with the highest NPV being the most favoured candidate for implementation. There are numerous canned computer

programs which will calculate the net present value providing the stream of cash flows and the discount rate are entered.

Where projects are not dollar valued, a benefit to cost ratio (BCR) can be established where the BCR is the net present value of the benefits, in units, divided by the net present value of the costs. Where a mixture of dollar values and weighted values is used, the two should be calculated separately and then presented to the decision-maker with a documented assessment of the effect that the BCR should have on the computed NPV.

D. SENSITIVITY ANALYSIS

The prediction of future events, such as cash flows, involves uncertainty. This is particularly true in such areas as applying a value to possible alternative uses for scarce resources, or estimating the retraining costs of displaced labour. The results of any cost/benefit analysis depend on the assumptions made about future cash flow behaviours. It is therefore important to have a feel for the likely accuracy of the computation made. A common method of doing this is to identify those factors which have the biggest effect on the calculation, then vary them over a reasonable range of values and observe their effect on the NPV analysis. This should give a good idea of the likely accuracy of the NPV calculation.

The analysis can go further and assign probabilities that various cash flows will occur should a particular alternative be implemented. The sum of the probabilities assigned to the envisaged cash flows must add to one for each alternative course of action studied. If the NPV of each and flow scenario for a particular alternative is then multiplied by the assessed probability of that scenario occuring, the sum of the NPV's for the scenarios so treated, will give an expected net present value for that alternative. This should give a better estimate of the likely outcomes for each possible course of action than does the raw net present value calculation. The higher accuracy of this method has to be traded off against the additional work it creates. This level of analysis is probably beyond that which the project manager should attempt using his own resources. It is incumbent on him to identify whether such an analysis is needed, and, if so, who should best perform it. It may well be that a funded study by a specialised economic analysis organisation is the most cost-effective approach.

An example of a cost/benefit analysis by Cylke, Mairs, Piatt and Waites of OP-162 is attached as Appendix A. [Ref.9] This analysis is not from the field of 'make or buy', but does serve to illustrate the general methodology to be followed.

VII. CONCLUSIONS

The question of whether to make or to buy a major weapons system is one of some national importance as it can impact directly on several areas that affect a nation's well-being. The decision on which way to proceed involves a trade-off between numerous factors, which can vary from ones which are easily quantified through to ones which might not even be recognised.

The process leading to a decision might seem to be unstructured and subjective at first sight, but, with some effort, the analysis of the problem can be broken down into its component parts and a form of structure introduced. It is beyond the resources of the project manager to conduct this analysis on his own. He must be aware of what he can do best and what he should pass to others. His overriding duty is to try to obtain the best value for the taxpayers' money. It is unlikely that the project manager will be the final decision-maker and so his duty will normally be to present, to higher authority, as many of the salient factors as he can in a well documented analysis of the alternatives available.

He should consider not only the initial investment phase of his project but also the through-life operating and support costs which might accrue from each contemplated

course of action. He must look beyond the confines of his own organisation and estimate the costs and benefits as they affect the taxpayer.

While reviewing the costs and benefits, it is likely that the project manager will find that neither total build nor total buy is the cheapest real cost option. The strength of a structured approach to the problem is that it should become clear which parts of the project should be undertaken using domestic resources and which should be undertaken elsewhere. Even the production of a list of projects which could be undertaken domestically, ranked from most cost effective to least cost effective, would be helpful to the decision-maker who is most probably looking for the maximum reasonable domestic involvement in the project. Where the decision-maker opts to produce at home things which appear to be uneconomic, he is applying a value to such unquantifiable factors as the national interest and national security.

The purpose of this paper was to set down a methodology and discuss some of the issues involved in reaching a make or buy decision. Hopefully it has demonstrated that a project manager can, with suitable help, produce a reasoned, sustainable argument, for presentation to the decision-maker, showing which of the identified alternatives he believes to be the one to follow. At best his recommendations will be accepted, at worst he can assume that, where his

recommendations were not accepted, he has been of some assistance to the decision-maker by laying out the factors involved in proceeding in particular directions.

The decision to make or to buy is one which may have an effect lasting for forty years, the average lifecycle of a major weapons project from approval to extinction. This paper attempted a light treatment of the topic and is intended to be nothing more than a framework on which the individual project manager can build his own analysis. There are many detailed reference works which the project manager can, and should, consult in order to achieve the best possible analysis within the many constraints with which he is presented.

APPENDIX A

ECONOMIC ANALYSIS EXAMPLE

Written by: Steve Cylke, Lee S.Mairs, C.W.Piatt and Wendell Waites. [Ref.9:Appendix]

The following is a sample economic analysis for an ADP system acquisition. This example is not intended to duplicate all the data collection, calculations and written material which should accompany a proper analysis -- thus, these results should not be used for making a policy decision. Rather, the primary objective is to illustrate the general process of cost/benefit analysis and the rationale behind it. Hopefully, the discussion and comments which accompany this analysis will clarify some of the more difficult concepts outlined in the preceding guide.

A. STATEMENT OF THE PROBLEM

The sample cost/benefit analysis chosen for this guide is the provision of ADP assistance to the Enlisted Community Managers (ECMs) in OP-132C. The ECMs manage the Navy's entire enlisted force, with each of the eleven ECMs responsible for several enlisted ratings. The ECM's work consists mainly of generating a large volume of correspondence, conducting data analyses, and presenting the results of these analyses in summary or graphical form.

The ECM section currently has no computer equipment. Although there is an OP-132 computer system, this system is utilized largely by the Officer Community Managers (OCMs). Also, the OP-132 computer does not have a letter-quality printer, which limits its value for producing correspondence. Currently, all data analyses by the ECMs are typed by five yeomen (YNs) on ordinary typewriters, not word processing equipment. About 40 percent of all correspondence typed by the TNs is for the ECMs and this correspondence normally requires a number of time-consuming revisions including retyping by the YNs, reviewing by the ECMs, further retyping, etc. In addition to typing, the YNs provide administrative support such as answering phones, maintaining office supplies, copying, filing and other administrative functions for the entire branch. Therefore, although this analysis concentrates on the YN time saved on typing correspondence, there are other areas (specifically, filing and copying) which would also benefit from automation.

It is anticipated that automation of the section would result in time savings for YNs typing correspondence, as well as for ECMs in analyzing data and producing graphs. As we discuss below, this time savings should imply either a shifting of YN and ECM work into other areas or, preferably, to manpower or billet reductions. Further, although there is no evidence of unaccomplished (untyped or incomplete) work, there is evidence that the quality of current work and

the quantity of potential work would be increased under a more automated system.

B. ALTERNATIVES CONSIDERED

We consider four alternatives in this cost/benefit analysis:

1. A highly-automated alternative with individual micro-computers for each ECM.

2. A highly-automated alternative with two large micro-computers with a terminal for each ECM.

3. An "intermediate" option which more intensively uses the OP-132 computer by adding a letter quality printer.

4. The current non-automated system (staus-quo).

The highly-automated alternatives have the following capabilities: text typing and editing (word processing) with spelling error checks; data filing, analysis and retrieval; programming in a high-level language (BASIC, FORTRAN, PL1, etc.); and graphics for the presentation of data and analyses. The hardware would consist of either a large micro-computer with a terminal for each ECM or a smaller micro-computer system for each ECM. Printing would be handled by a single dot-matrix printer for preliminary drafts and a letter-quality printer for final copies.

With the highly-automated alternatives, the ECMs themselves would assume much of the initial typing work. The YNs' role would be to place correspondence in proper Navy format and to type corrections to correspondence as requested. The highly-automated alternatives would provide one

additional terminal or one portable computer to the YNs for this reason. Since the initial draft typing function would be transferred from YNs to ECMs, the total number of YNs can be reduced.

The intermediate solution involves increased use of the existing OP-132 system by adding a letter-quality printer. The OP-132 system already has word processing, spelling error check, and programming (BASIC language) capabilities. There is one terminal currently available to OP-132. (Another terminal is connected to the system but it is used by OP-134 personnel.) The addition of a letter-quality printer would reduce the time required to produce correspondence. Since only one terminal would be available under this alternative, the word processing capability would be used mostly by the YNs, and it is not anticipated that a staff reduction would be possible. As we discuss below, this alternative would produce some (reduced amounts of) time savings in typing correspondence as well as improved quality and quantity of ECM output.

The final alternative is the status quo. The status quo is a default option which is chosen only if the other alternatives are not economically justified. As is discussed in the text, this is a very common means of including the status quo in the cost/benefit comparison. When used as a default alternative, it is also implicitly assumed that the status quo is itself economically justified. Thus, we only

need to consider the marginal (or additional) costs and benefits of the proposed alternatives relative to the status quo. The cost savings from replacing the status quo with an alternative are considered as benefits of adopting that alternative.

The decision rule is that if the net present value of additional benefits (including cost savings) exceeds the net present costs, that alternative is preferred to the status quo. If all the alternatives have a positive net present value, then the alternative with the highest net present value is the most preferred. On the other hand, if costs exceed benefits (and cost savings) for all the alternatives, the status quo is preferred.

C. BENEFIT ANALYSIS

The followng are the primary benefits or cost savings expected from the new ADP system alternatives:

1. Reduction in time required to produce correspondence.

2. Reduction in time required to produce analyses of data and graphs.

3. Improved quality of the final product - ie., reduced errors associated with hand tabulation of data and editing of correspondence; improved quality of graphs.

4. Improved cataloging and filing of information - easier to train and update new personnel; easier to retrieve and transfer information between ECMs and others with similar systems.

5. Improved access to force projection models and data, many of which are currently stored and run on similar systems.

6. Increased ECM output due to reduced response time to the many time-sensitive items which would not be completed or even attempted under the current system.

The highly-automated system is expected to provide benefits (cost-savings) in all the above categories. The intermediate solution is expected to provide benefits in categories 1, 3, and 6, since only increased word-processing capabilities are included in the system.

The next issue is how these benefits should be quantified. The text presents several possible approaches to measuring benefits. As we mention above, since the status quo is assumed to be economically justified, we only need to measure the changes in costs and benefits from that baseline.

1. <u>Benefits from Highly-Automated Systems</u>

The highly automated alternatives produce measurable benefits and resource savings in three specific areas.

a. The Reduction in Time Required for Current Levels of Correspondence

The transfer of initial typing from the YNs to the ECMs will result in YN time savings for typing correspondence. On the other hand, we anticipate no net increased time required for the ECMs since correspondence can normally be composed at the typewriter at least as easily as by longhand. In fact, the quicker turn-around time for corrections and revisions will more than offset any additional ECM time which might be required for initial typing of the

correspondence. In order to provide a conservative estimate of potential savings, however, it will be assumed that the ECMs' time requirements for current levels of correspondence are the same with or without the ADP system. Thus, the cost savings from typing of correspondence are based on the savings of YNs' time only.

b. The Reduction in Time Required to Produce Current Graphics

The benefits for reduction in graphics time is based on the time savings expected with the current amount of required graphics material prepared by the ECMs. The normal graphics requirements for the ECMs is 6 graphs for each of the 99 ratings per quarter. It is estimated that these graphs take about an hour each to prepare. The time to produce these graphs with the ADP system is expected to be about ten minutes for each.

c. Increase in Both the Quantity and Quality of ECM Output

To measure the benefits of improved ECM output we conducte the following experiment: By surveying ECMs and observing other organizations which have similar systems, we estimated the current ECM time required to produce the same quantity and quality expected under the highly-automated systems. In economic terms, this extra potential output (estimated, conservatively, at 10% of current ECM time) is an "opportunity cost" of not having an automated system. However, since this quality and quantity is not currently

being produced, we cannot assume that all this time would have full benefit (ie., would be demanded) by the Navy. As a rough approximation, therefore, we took half the additional ECM time (5%) as the added output value resulting from the highly automated systems. (Although the assumptions used here may appear somewhat arbitrary, we "test" their impact on the final decision by conducting a sensitivity analysis. As we stress in the guide, it is important to quantify wherever possible.)

2. <u>Benefits from the Intermediate Option</u>

The measurable benefits from the intermediate option include two of the three benefits from the highly-automated alternatives - reduced correspondence time and increased quantity and quality of ECM output. (No graphics capability is provided.) The size of these benefits will be significantly smaller, however, since all eleven ECMs and (YNs) would share one terminal with the OCMs. To estimate benefits in this situation, we start with the same values as under the highly-automated alternatives. We then reduce these benefits by 90% since there is only one, rather than ten, terminals.

However, even this benefit estimate may be overstated since the one terminal will be shared with the OCMs and queues may delay or deter use of the terminal. To capture this effect, we observe that a normal terminal is idle about 50% of the time - this is currently the case with

the OP-132 terminal. (Thus, if ECM and OCM demand for that terminal could be perfectly coordinated, benefits from this alternative would be exactly 10% of the highly automated benefits.) Based on previous OP-01 experience, we estimate that waiting time reduces effective availibility of the terminal to about 60% of its normal (undelayed) usage. This implies a net benefit from the third alternative which is roughly 6% (or .6 x 10%) of the benefit value of the other highly-automated alternatives. This 6% factor is used to calculate the benefits of reduced typing time and increased ECM output resulting from the third alternative. (Again, one may object to these figures as somewhat arbitrary, yet sensitivity analysis will show the impact of the assumptions on the final result. If the net present values of the alternatives are close, then further "evidence" may be required before making a decision.)

3. <u>Summary of Benefits</u>

Estimates of the benefit values for each alternative are summarized in Table I below. The base year for operation of the system is assumed to be 1985, with a system life of 5 years. Table I shows annual benefits of roughly $115,000 for the highly-automated systems and $3,600 for the intermediate option. The present value of benefits using a 10% discount rate is $436,000 for Alternatives 1 and 2, and $13,600 for Alternative 3.

Table I

Annual Benefits from ADP Systems Alternatives for OP-132C

BENEFIT COMPUTATION: ALTERNATIVES 1 AND 2 (HIGHLY AUTOMATED)

Category	(a) Average Annual Billet Cost	(b) Billet Cost per Man-Hour of Work	(c) Current Hours Required	(d) Time Required With ADP Assistance	(e) Benefits (b)x(c-d)
Typing Correspondence	\$22,600 (7)	\$14	\$2,774 (2)	\$277 (3)	\$34,958
Producing Graphs	45,300 (4)	28	2,376	396 (5)	55,440
Output Quality & Quantity	45,300	28	17,741 (1)	16,854 (6)	24,836
				TOTAL ANNUAL BENEFIT: ALTERNATIVES 1 AND 2	\$115,234

NOTES: (See Attached)

BENEFIT COMPUTATION: ALTERNATIVE 3 (LETTER-QUALITY PRINTER ONLY)

The annual benefits for Alternative 3 (adding a letter-quality printer to the existing OP-132 system) are:

Benefit from typing correspondence	-	\$2,100
Increased quantitative/qualitative ECM output	-	1,500
TOTAL ANNUAL BENEFIT: ALTERNATIVE 3		\$3,600

Notes to Table I

(1) This is the total annual ECM hours. It assumes an average of 21 working days per month, a 40 hour workweek, and a 20% average absentee rate due to leave, etc.

(2) The total annual typing requirements are based upon the current YN typing load and assumes 10 minutes to type each page.

(3) We estimate that the total YN typing effort under the highly-automated system would be approximately 10% of the current amount. This estimate was obtained through interviews with ECMs and YNs, and observation of automation changes in similar Navy organizations.

(4) The average annual cost for an ECM is based upon the weighted average of the billet cost for eight O-5s, one O-4, one O-3, and one E-9.

(5) The amount of time spent on graphics under the highly-automated systems assumes a reduction in time from 1 hour to 10 minutes per graph. This information was obtained through interviews with ECMs, observation of current graphics production, and knowledge of the comparative advantages of automated graphics.

(6) The difference between this figure and the current ECM hours reflects the additional ECM time required (under the current system) to produce the same quality and quantity of output which could be attained under a highly-automated system. For the current estimate we used a 10% difference in output quality and quantity, which we translate to roughly a 5% difference in required hours. This is a very conservative estimate based upon interviews with ECMs, observation of the ECM work process, and comparison with similar organizations which have converted from manual to automated processing.

(7) The annual cost for a YN is based upon weighted average billet cost for one E-7, one E-5, and two E-4s.

A key assumption underlying the estimates in Table I is that the time-savings benefits for correspondence and graphics are valued at the billet cost of the personnel (YNs and ECMs) involved. This implies one of two situations resulting from automation. In the first case, automation releases personnel to perform other work which has a value to the Navy equal to their billet cost. In the second (preferred) case, automation allows the Navy to reduce the total manpower (YNs) required to do the work. In either case, the cost savings is appropriately valued at the billet cost of ECMs' or YNs' time.

D. COST ANALYSIS

Estimated costs for the ADP alternatives were obtained from discussions with local vendors of computer equipment. These include costs for acquisition, operation and maintenance, software, disk storage, and training. Training costs include fee to the vendors and the billet costs for the Navy personnel being trained. Because of the 2-3 year rotation period of the ECMs, billet training costs are expended three times during the five-year ADP system life-cycle.

For the individual portable computer system, costs are based on Kaypro II systems which have 64K of random access memory (RAM) each. The large computer system considered would also provide 64K of RAM to each user.

Table II
Annual Costs for the ADP System Alternatives

Alternative 1-Individual Computers

Cost Item	1985	1986	1987	1988	1989	Salvage Value (10% of Original Hardware cost)
Hardware and Software	$22,000	----	----	----	----	$2,200
Maintenance	3,000	$3,000	$3,000	$3,000	$3,000	
Disk Storage	1,100	1,100	1,100	1,100	1,100	
Training Direct cost	200	----	----	----	----	
Navy Opportunity Cost	300	----	150	150	----	
Total	$26,600	$4,100	$4,250	$4,250	$4,100	

Alternative 2-Large Computer System

Cost Item	1985	1986	1987	1988	1989	Salvage Value (10% of Original Hardware cost)
Hardware and Software	$41,200	----	----	----	----	$4,100
Maintenance	5,000	$5,000	$5,000	$5,000	$5,000	
Training Direct cost	500	----	----	----	----	
Navy Opportunity Cost	300	----	150	150	----	
Total	$47,000	$5,000	$5,150	$5,150	$5,000	

Alternative 3-Printer for Current OP-132 System

Cost Item	1985	1986	1987	1988	1989	Salvage Value (10% of Original Hardware Cost)
Letter-Quality Printer	$3900	----	----	----	----	$390
Maintenance	300	$300	$300	$300	$300	
Training Direct Cost	200	----	----	----	----	
Navy Opportunity Cost	44	----	30	14	----	
Total	$4444	$300	$330	$314	$300	

The costs for the intermediate solution include only the initial cost of a letter quality printer and reduced maintenance (10%) and training costs (about 15%) over the life-cycle. (Opportunity costs of training ECMs are reduced, but the total costs of contractor-provided training remain the same.)

The costs for the ADP system for each year of the life-cycle are shown in Table II. As in benefit computation, costs are converted to a present value basis by discounting costs occurring in future years (at 10%). The present value of costs for the individual portable computer is $35,000. (This includes the deduction of salvage value at the end of the project life.) The present value of costs for the large computer system is $55,000 while the net present cost of the intermediate option is only about $4,700.

E. SENSITIVITY ANALYSIS AND CONCLUSIONS

To determine the most preferred alternative, we now simply take the difference between the net present value of benefits and costs for each option. Under the baseline assumptions the net present value for the two highly-automated options (Alternatives 1 and 2) are $401,000 and $381,000 respectively. The net present value of the intermediate option (Alternative 3) is only $8,900. Since all three options have positive net present values, they are all preferred to the status quo. The individual computer option

(Alternative 1) is the most preferred of the three, while the net present value of Alternative 3 is insignificant in comparison to the other two.

Sensitivity analysis tests the "strength" of these conclusions under alternative assumptions about the future costs and benefits involved. Since future benefits (and cost savings) are based upon more tenuous assumptions than costs, we should vary benefits proportionately more than costs. To test the sensitivity of our results, we ask the question: would we still prefer an automated alternative if benefits were 50% lower and/or costs were 10% higher?

Under these assumptions the net present value of benefits from Alternatives 1 and 2 would be reduced to $218,000 and net present costs would increase to $39,000 and $61,000 respectively. Thus, even with large reductions in benefits and significant increases in costs, both highly-automated alternatives have large, positive net present values and remain cost-effective relative to the status quo. In fact, given the baseline cost estimates for Alternatives 1 and 2, the benefits from these options would have to be reduced by 92% and 87% respectively, before the status quo would become the preferred alternative.

Finally, despite the fact that the two highly-automated alternatives show significant positive net present values, their ultimate desirability hinges on whether or not manpower savings can be realized. If YN billets are not given

up to buy the new systems (and ECMs are not productive with their newly available time) then the status quo remains the most economic alternative. In fact, the unwillingness (or inability) of Navy managers to trade manpower for efficiency may be the reason why many Navy organizations have not been automated to date.

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